Prepared by the Science
Teachers' Association of
Western Australia (Inc).

ISSN 0725-6906

Physics

2001 TEE Solutions*

Production, Distribution and Sales:
Science Teachers' Association of
Western Australia (Inc).
PO Box 1099
Osborne Park 6916

Question papers and solutions can be obtained from:
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*These solutions are not a marking key. They are a guide to the possible answers at a depth that might be expected of Year 12 students. It is unlikely that all possible answers to the questions are covered in these solutions.

 STAWA appreciates the support of the Curriculum Council, which provided the marker's guides used a basis for these solutions.

TEE Physics 2001 Solutions

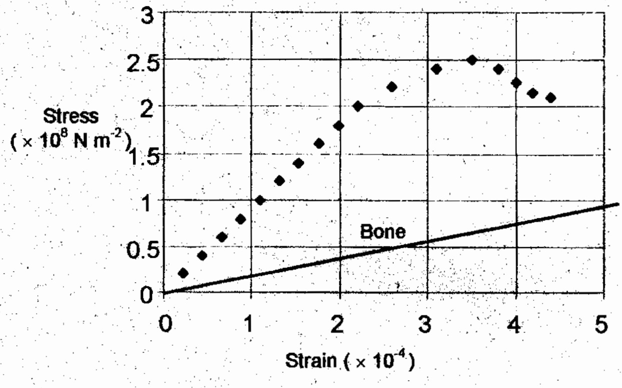
SECTION A

1. a) Always alternating.
   Transformers can only produce an output if there is a changing flux in the primary coil. This is achieved by an alternating input.

2. a) Stable equilibrium.
   If a person is balancing on one leg the centre of mass must lie above the base and ΣACM = ΣCM. When standing on one foot, a persons centre of mass will lie above the area of their foot. A non zero, displacement is needed to cause the person to topple.

3. Beats are heard when two notes of slightly different frequencies are played at the same time. Beats are a result of interference, where the two separate waves are alternately in and out of phase. For example two tuning forks of slightly different prong masses vibrating at the same time.

4.



   Slope of bone graph = 0.17 X 10^{11} Pa (Young's modulus of bone from the data sheet). On the scale given it will be a straight line across the whole area shown passing just below point (5,1)

5. The counterweight on the left of the jib gives an anticlockwise torque that counteracts the clockwise torque of the load. This weight must be large to balance the large clockwise torque produced when the load is far to the right.

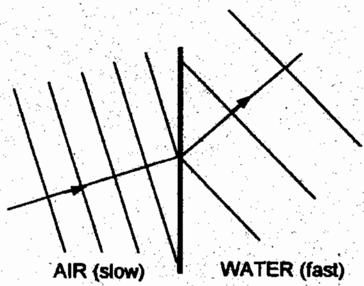
6. 77.5 dB represents an intensity of $10^{7.75} \times 10^{-12} = 10^{-4.25} = 5.62 \times 10^{-5}$ Wm^{-2}
   Assuming 20 violins, the total intensity will be 20 x 5.62 x 10^{-5} =
   1.125×10^{-3} Wm^{-2}
   New sound level = 10 log [$1.125 \times 10^{-3}/10^{-12}$] = 90.5 dB

7. Yes, the ISS is always affected by the Earth's gravitational pull according to Newton's Law. $F = Gm_1m_2/r^2$.
   This force is responsible for the centripetal acceleration of the ISS.

8. Estimate the radius of a basketball hoop to be 20 cm. Area $\approx \pi(0.2^2) \approx 0.04\pi$
$\Phi = BA \approx 50 \times 10^{-6} \times 0.1257 \approx 6 \times 10^{-6}$ Wb

9. Estimate a frequency of 100 MHz (typical for an FM station)
$E = hF = 6.63 \times 10^{-34} \times 100 \times 10^{6}$
$\approx 6.63 \times 10^{-26}$ J $\approx 4 \times 10^{-7}$ eV
[The order of magnitude would be different if you chose to use a figure typical for an AM station. You could also choose to select a frequency from the data sheet]

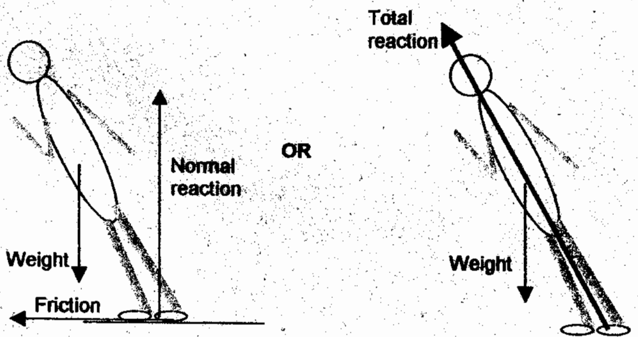
10.



The relative speed in each medium determines whether and how much the sound will refract.

11. Estimate a mass for the eagle of 5 kg.
Centripetal force + gravitational pull $= mv^2/r + mg$
$= \dfrac{5 \times 24^2}{85} + 5 \times 9.8 \approx 80$ N

12.



13. Direction of travel must be tangential to the magnetic field line.

14. To minimise power loss it is transmitted at high voltages.
As $P = VI$, the higher the voltage, the lower the current **for a constant amount of power transmitted**. Power dissipated as heat due to the resistance of the transmission lines depends on the square of the current ($P = I^2 R$) so the lower the current the less the power dissipated as heat, for the same quantity of power transmitted.

14. The surface speed of the Earth is greatest at the equator, as the effective radius of rotation is greatest ($v = 2\pi r/t$). The surface, itself, is accelerating downwards at a rate of v^2/r (centripetal) in the same direction as g, which makes the apparent acceleration of object at the equator less.

SECTION B

1. (a) (i) Minimum energy = 5.13 eV

(ii) The arrow represents an electron falling from a higher to a lower quantum energy state. This transition results in the emission of a photon.

(b) (i) Electron transitions are from -3.026 and -3.028 eV to the ground state (-5.130 eV). Each of these transitions produces photons with a slightly different wavelength.

$$\lambda = \frac{hc}{E_{photon}} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{2.103 \times 1.6 \times 10^{-19}} \approx 6 \times 10^{-7} \text{ m}$$

(ii) A lower energy will give a longer wavelength photon as $E \propto {}^1/_\lambda$
Any transition less than 2.1 eV will give a longer wavelength.

(c)A (i) The spectrum of a star consists of discrete patterns of lines that are emitted when the atoms of particular elements are de-excited. By matching these patterns to the emission spectra of known elements, the elements on the star can be identified.

(ii) One benefit: Ultraviolet radiation causes photosynthesis to occur in plants on Earth.
Principle: The energy contained in a UV photon is large enough to cause CO_2 to react with water in a plant to produce starch.
[Other possible answers are acceptable.]

(c)B (i) Lasers contain an elemental gas that is excited to emit photon wavelengths which are characteristic of that element.

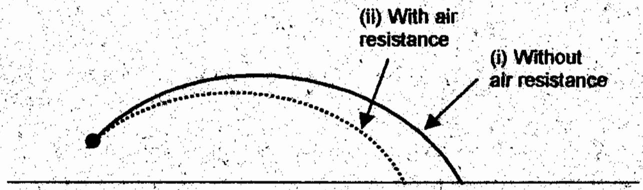
(ii) Benefit: X-ray photography can be used to produce images of broken bones or other internal faults with the body.
Principle: X-ray photons have very high energy and can penetrate solid objects such as bone. Bone absorbs X-rays to a

greater extent than flesh and hence allow less exposure in an X-ray photograph.

(c)C (i) Street discharge lamps contain one or more gases. Each gas gives a discrete set of photon energies which show up as lines in a dispersed spectrum. The apparent colour of the lamp depends on the particular set of photon energies produced by the lamp. White light is a mixture of all colours.

(ii) Benefit: : X-ray photography can be used to produce images of cracks or defects within metal parts.
Principle: X-ray photons have very high energy and can penetrate solid objects. Metal absorbs X-rays to a greater extent than a crack or defect and hence the defects show up as greater exposure in an X-ray photograph.

2. (a)



(ii) Air resistance is a drag force that acts on the ball while it is moving and always opposes velocity. Under air resistance the ball will hit the ground earlier and fall shorter

(iii) There will be no time when the acceleration of the ball is zero as gravitational force is acting on it at all times which produces a constant acceleration towards the Earth.

(b) (i) $u_v = 55 \sin 1.5 = 1.440 \text{ ms}^{-1}$
$u_h = 55 \cos 1.5 = 54.98 \text{ ms}^{-1}$
Vertically: $s = ut + {}^1/_2 at^2 \Rightarrow -0.35 = 1.440t - 4.9t^2$
Solving for t: time of flight t = 0.452 s

(ii) Horizontal distance travelled, $s_h = u_h \times t = 54.98 \times 0.452$
$= 24.8$ m

3. (a) (i) As v^2 is directly proportional to T a graph of v^2 versus T will be a straight line which is easier to draw (best fit) and process.

(ii) μ units are force units/ velocity² units $= \dfrac{\text{mass x acceleration units}}{(\text{ms}^{-1})^2}$

$= \dfrac{\text{kg.m.s}^{-2}}{\text{m}^2.\text{s}^{-2}} \quad = \text{kg m}^{-1}$

(b) Slope = $\frac{(45000 - 15000)}{(210 - 75)} = 222.2$

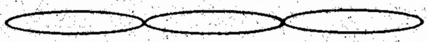
Slope = $v^2/T = 1/\mu$ so $\mu = 1/\text{slope} = 4.5 \times 10^{-3}\ \text{kgm}^{-1}$

(c) Wave velocity = $\sqrt{\frac{T}{\mu}} = \sqrt{\frac{125}{4.5 \times 10^{-3}}} = 167\ \text{ms}^{-1}$

Wavelength = $2 \times 0.76 = 1.52$

frequency = $\frac{v}{\lambda} = \frac{167}{1.52} = 110$ Hz

(d) (i)

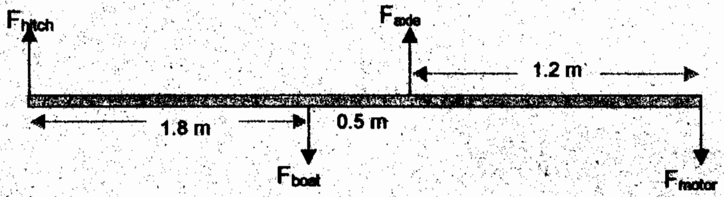


2nd overtone

(ii) The transverse wave moving along the string causes it to vibrate at right angles to the wave velocity. The string may alternatively compress and rarefy the air it is in contact with. These pressure waves travel out in all directions from the string as longitudinal vibrations.

4. (a) The direction of the force is **upwards** because the torque produced by the weight of the trailer about the axle is anticlockwise. This means that the force acting on the tow bar is downwards, so an equal and opposite force must act upwards on the ball hitch.

(b)



Σ Clockwise torques = Σ Anticlockwise torques

Taking torques about the axle and guessing that F_{hitch} is upwards:

$$F_{hitch} \times 2.3 + F_{motor} \times 1.2 = F_{boat} \times 0.5$$

$$F_{hitch} = \frac{650 \times 9.8 \times 0.5 - 7.2 \times 9.8 \times 1.2}{2.3}$$

F_{hitch} = 1020 N (positive so "upwards" is correct)

(c)A The force, F, on the ball hitch is a large distance, r, from the pivot thus creating a large torque since $\tau = r F \sin\theta$. The boat's centre of mass is much closer to the pivot and so the force needed at the hitch is much smaller than the boat's mass to exert the same balancing torque and produce equilibrium.

(b) Slope = $\frac{(45000 - 15000)}{(210 - 75)} = 222.2$

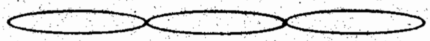
Slope = $v^2/T = 1/\mu$ so $\mu = 1/\text{slope} = 4.5 \times 10^{-3}$ kgm^{-1}

(c) Wave velocity = $\sqrt{\frac{T}{\mu}} = \sqrt{\frac{125}{4.5 \times 10^{-3}}}$ = 167 ms^{-1}

Wavelength = 2 x 0.76 = 1.52

frequency = $\frac{v}{\lambda} = \frac{167}{1.52}$ = 110 Hz

(d) (i)



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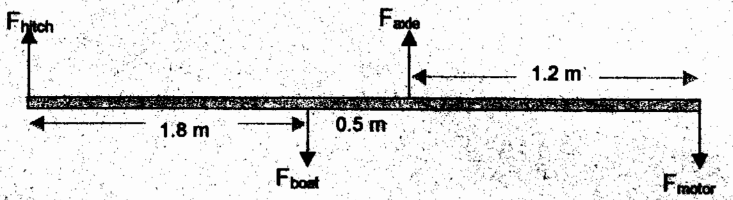

Σ Clockwise torques = Σ Anticlockwise torques

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(c)A The force, F, on the ball hitch is a large distance, r, from the pivot thus creating a large torque since $\tau = \mathbf{r\ F\ sin\theta}$. The boat's centre of mass is much closer to the pivot and so the force needed at the hitch is much smaller than the boat's mass to exert the same balancing torque and produce equilibrium.

$F = ma = \frac{GMm}{r^2}$

(c)B In each case, the weight is about the same. When the person is supported on their toes, their arms are about twice as far from the pivot as their centre of mass. Their arms would need to supply a force about half of their weight. When they are supported on their knees, their arms are about three times as far from the pivot as their centre of mass. Their arms would therefore only have to supply a force about one third of their weight.

5. (a) $g = \frac{GM}{r^2} = \frac{6.67 \times 10^{-11} \times 1.11 \times 10^{21}}{(3.86 \times 10^5)^2}$

$= 0.497\ ms^{-2}$

(b) $a = \frac{F}{m} = \frac{Gm}{r^2} = \frac{6.67 \times 10^{-11} \times 1.99 \times 10^{30}}{(4.14 \times 10^{11})^2} = 7.74 \times 10^{-4}\ ms^{-2}$

(c) $a = v^2/r$ so $v = \sqrt{(ar)} = \sqrt{(7.74 \times 10^{-4} \times 4.14 \times 10^{11})}$

$v = 1.79 \times 10^4\ ms^{-1}$

(d) Estimate radius of wire = 0.05 mm (5×10^{-5} m)

$e = \frac{Fl}{AY} = \frac{1.5 \times 0.0497 \times 2}{\pi(0.05 \times 10^{-3})^2 \times 1.16 \times 10^{11}}$

$= 1.7$ mm

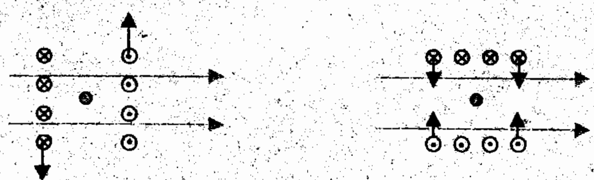
6. (a) $F = IlB \quad l = 1\ cm = 1 \times 10^{-2}\ m$

$= 5.6 \times 1 \times 10^{-2} \times 0.45 = 0.0252\ N$

(b) Maximum torque= $F\ l\ r\ N\ 2 = (0.0252)(0.225)(0.06)(420)(2)$

$= 28.6$ Nm

(c)



Position 1 - maximum torque Position 3 - minimum torque

7. (a) Magnetic field is vertically downwards at the North pole. The Earth's geographic north pole is like a magnetic south-seeking pole.

(b) Maximum emf occurs at the bottom of the girl's swing. At this point the seat will be cutting the vertical component of the field at right angles (maximum angle) and will also be moving at the fastest speed (Emf is proportional to the rate of flux cut).

(c) Graph A is most likely. The emf must reverse as the swing reverses its direction of cutting flux each swing (must be A or B). The change of flux would be a smooth, curved function and not an immediate change, so cannot be B.

SECTION C

1. (a) Compton scattering demonstrates the particle nature of radiation. Momentum of an impact is required to scatter an electron so the radiation must have momentum, which is usually associated with particles.

(b) Electron momentum: $p = mv \Rightarrow kgms^{-1}$

Photon: $p = \frac{h}{\lambda} \Rightarrow \frac{Js}{m} \Rightarrow \frac{m\,a\,m\,s}{m} \Rightarrow \frac{kg\,m^2s^{-2}s}{m}$

$= kgms^{-1}$ (same)

(c) (i) An X-ray has a larger momentum as it has a smaller wavelength as $p = h/\lambda$, p must be larger.

(ii) $110\ keV = 110 \times 10^3 \times 1.6 \times 10^{-19}\ J = 1.76 \times 10^{-14}\ J$

$\lambda = \frac{hc}{E}$ and $p = \frac{h}{\lambda}$ substituting for λ: $p = \frac{hE}{hc}$

$p = \frac{1.76 \times 10^{-14}}{3 \times 10^8} = 5.87 \times 10^{-23}\ kgms^{-1}$

(iii) Lowest energy means largest value of wavelength λ so $(1 - \cos\theta)$ must take its largest value ie $\cos\theta$ must be -1, so θ must be 180^0

(d) $\lambda' = \lambda + \frac{h}{mc}(1 - \cos\theta) = \frac{hc}{E} + \frac{h}{mc}(1 - \cos 60)$

$= 1.13 \times 10^{-11} + 1.21 \times 10^{-12}$

$\lambda' = 1.25 \times 10^{-11}\ m$

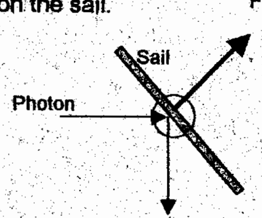
Energy of scattered photon is:

$E' = \frac{hc}{\lambda'} = 1.59 \times 10^{-14}\ J$

Therefore the energy of the scattered electron must be:

$1.76 \times 10^{-14} - 1.59 \times 10^{-14}\ J = 1.71 \times 10^{-15}\ J$

(e) Newton's Law states that a change of momentum is caused by a force. Since the scattering causes a change of momentum of the photons, the sail must exert a force on the photons as they are reflected. The photons must therefore exert a reaction force on the sail.



2. (a) Magnetic moment is a vector
Magnetic moments have size and direction.
Magnetic moments can add to zero.

(b) You would not expect to have a constant frequency.
The sizes of the magnetic domains are different and they flip at random. The graph in Figure 13 shows the random time intervals between each event.

(c) Buzzing sound is a noise.
The graph shows no pattern in the time intervals between pulses.
Random pulses would constitute noise rather than a note.

(d) The diagram should show all the magnetic domains aligned in the same direction which will be opposite to the imposed field direction.
For example: